Management Measure 4
Site Development

A. Management Measure

Plan, design, and develop sites to

- Maintain predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, or detain runoff.
- Protect areas that provide important water quality benefits or are particularly susceptible to erosion and sediment loss.
- Limit increases of impervious areas unless predevelopment site hydrology is maintained.
- Limit land disturbance activities, such as clearing and grading and cut-and-fill, to reduce erosion and sediment loss.
- Limit disturbance of natural drainage features and vegetation.

B. Management Measure Description and Selection

1. Description

The goals of this management measure are to reduce the generation of nonpoint source pollution, maintain natural hydrology, and mitigate the impacts of urban runoff and associated pollutants from all site development, including activities associated with roads, highways, and bridges. Included in this section are management practices that can be applied during the site planning and review process to ensure that nonpoint source pollution and increases in the volume and rate of runoff are appropriately managed during and after construction.

Although the goals of Management Measure 3 (watershed protection) are similar, this measure is intended to apply to individual sites at the catchment level (see Figure 1.3) rather than larger watersheds or regional drainage basins. The site development and watershed protection management measures are intended to complement each other and be used together within a comprehensive framework to control runoff and reduce nonpoint source pollution.

- Programs designed to control increased runoff and nonpoint source pollution resulting from site development should include
- Predevelopment planning to match the goals of the developer to the attributes of the site.

- Guidance on creating site designs that closely maintain predevelopment hydrologic functions.
- Appropriate pollution prevention practices to be incorporated into site development and use.
- Site plan review and conditional approval to ensure that the integrity of environmentally sensitive areas and areas necessary for maintaining natural hydrology and water quality will not be lost.
- Requirements for erosion and sediment control plan review and approval prior to issuance of appropriate development permits.

In addition to the preceding provisions, the following objectives should be incorporated into the site development process:

- During site development, disturb only the smallest area necessary to perform current activities to reduce erosion and off-site transport of sediment.
- Avoid disturbance of unstable soils or soils particularly susceptible to erosion and sediment loss.
- Favor sites where development will minimize erosion and sediment loss.
- Protect and retain existing vegetation to decrease concentrated flows, maintain site hydrology, and control erosion.
- Minimize imperviousness to the extent practicable.
- Properly manage all maintained landscapes to avoid water quality impacts.
- Use natural hydrology as a design element and avoid alteration, modification, or destruction of natural drainage features.
- Design sites to preserve vegetated or natural buffers adjacent to receiving waters.

The use of site planning and evaluation can significantly reduce the size of controls required to retain sediment on-site. Long-term maintenance burdens can also be reduced. Good site planning can attenuate runoff from development and can improve the effectiveness of the conveyance and treatment components of an urban runoff management system (Anacostia Restoration Team, 1992).

2. Management Measure Selection

This management measure was selected because the practices associated with it have been shown to be effective at protecting natural drainage features, reducing runoff quantity, and improving runoff quality. Site evaluation and protection of features that promote infiltration, filtration, and on-site detention will protect receiving water quality, maintain baseflow in receiving waters, and prevent or reduce further degradation of stream channels. Development in and around urban areas is inevitable as population growth puts pressure on suburbs and rural areas. This management measure recommends standards for new development that minimize environmental damage caused by that development while allowing for population and economic growth.

Increasing Housing Prices and Environmental Regulation

Laquatra and Potter (2000) undertook a study to determine whether there is a linkage between the costs of complying with environmental regulations and increasing housing prices. In their study, they provide evidence challenging the notion that the decline in homeownership since the 1960s can be attributed to increasing housing prices resulting from the financial burdens being imposed on land developers by environmental regulations.

In response to the belief that increasing environmental compliance costs have led to rising housing prices, the authors point out that the period from 1963 to 1973, when very few environmental regulations were in existence, witnessed an increase in the price of new homes. In addition, the authors explain that in the northeastern region of the United States, real house prices actually declined from 1973 to 1983, even though a number of new environmental regulations were being implemented during that time. However, real house prices in the South and West (excluding the west coast) increased during the same period despite the fact that these regions are considered less environmentally progressive than the Northeast.

The authors cite another study that examines the economic impacts of the federal Endangered Species Act (ESA) on building costs and home prices in the Pacific Northwest. The study analyzed the relationship between the listing of the spotted owl as an endangered species and prices for lumber and new homes. The results indicated that no significant relationship existed between the spotted owl listing and increases in the average cost of a new home.

Other factors to which the authors attribute the reduction in homeownership rates include

- Changing demographics, most notably the delaying of marriage and the age when couples begin having families, as well as the rise in the number of single-household families.
- A decline in housing affordability, which stems from income levels that have failed to keep pace with rising home prices. Incomes became stagnant or began to decline with the onset of globalization, which resulted in the transferring of manufacturing jobs overseas. These manufacturing jobs were replaced by lower-paying jobs in the service industry.
- Rapid inflation during the 1970s and 1980s that prevented many Americans from purchasing homes.
- The inability of first-time homebuyers to make down payments because of increasing levels of consumer debt and low personal savings rates. These financial shortcomings force many potential homebuyers to wait longer before they are able to purchase a home.

Many researchers agree that housing price increases are primarily due to factors related to improvements in the quality of housing, such as the building of larger homes and enhancements in amenity features of new homes. Other housing researchers point out that local zoning and subdivision ordinances contribute to increasing housing costs. The authors conclude that there are insufficient data to support the argument that the costs of complying with environmental regulations have resulted in higher home prices. Housing affordability problems are more likely the result of demographic trends, declining incomes, lifestyle and societal changes, inflation, and rising interest rates.

A Better Site Design Approach to Runoff Management: Low-Impact Development

The goal of low-impact development (LID) is to maintain and enhance the predevelopment hydrologic regime of urban and developing watersheds. LID focuses on managing runoff in small, cost-effective landscape features on each lot rather than conveying runoff to large, costly storm water ponds located at the bottom of large drainage areas. Hydrologic functions such as infiltration, ground water recharge, and depressional storage are maintained using simple, small-scale practices such as bioretention facilities. A key objective of LID is to reduce the hydraulic connectivity of impervious surfaces. Instead of allowing storm water to run from a downspout down a driveway and into a storm sewer, water is directed onto a lawn or other pervious area. By disconnecting rooftop runoff from the storm drainage system, a community can decrease the volume of water conveyed to a storm drain by as much as 50 percent (Pitt, 1986). To avoid soggy areas in lawns, water can be directed to specially designed depression storage areas such as bioretention or infiltration areas.

The following is a list of fundamental practices of the LID approach that can be included in runoff management plans. These practices are presented in two publications by the Department of Environmental Resources of Prince George's County, Maryland: *Low-Impact Development Design Strategies: An Integrated Design Approach* (2000a) and *Low Impact Development Hydrologic Analysis* (2000b).

- *Use hydrology as the integrating framework.* Hydrology is used as the key feature when designing a development. Areas that play a critical role in the movement of water (e.g., streams, riparian and buffer areas, floodplains, wetlands, and ground water recharge sites) are identified first. Alternative layout schemes are then evaluated in terms of their impact on site hydrology. Key objectives are to minimize the amount of impervious cover created and to make created impervious areas function as "ineffective" impervious areas that are not directly connected to a storm drain network.
- *Think micromanagement.* Site hydrology is analyzed and dealt with at small scales. Using natural drainage as a design element, integrated management practices are scattered throughout the site, allowing for runoff distribution and the retention of natural hydrologic functions such as infiltration, depressional storage, and interception.
- *Control runoff at the source.* Management of runoff at or near the sources eliminates the need for large-scale runoff management practices such as concrete conveyance systems and storm water ponds.
- *Incorporate safety features into the design of management practices*. LID practices might require diversions or drainage to allow for overflow of runoff from large storms and storm events that occur during saturated conditions. This emergency drainage will protect the longevity of the structural practice against damage from high runoff volumes and flow velocities and enhance the acceptance of LID in the community.
- *Use simple, nonstructural methods.* Natural hydrologic functions rely on simple processes that promote infiltration, depressional storage, and interception of storm water. These characteristics can be implemented throughout the site using simple methods that incorporate native plants, soil, and gravel.
- *Create a multifunctional landscape.* A goal of the LID approach is to create a landscape where runoff is micromanaged and controlled at the source. Practices and natural landscape features work together to reduce postdevelopment runoff volume and maintain the predevelopment time of concentration.

The Prince George's County LID publications can be ordered through the Internet at EPA's National Service Center for Environmental Publications web site at www.epa.gov/ncepihom. They can also be ordered by phone, fax, or mail from USEPA/NSCEP, P.O. Box 42419, Cincinnati, Ohio 45242-2419, toll-free 800-490-9198, fax 513-489-8695.

Better Site Design and the Site Planning Roundtable

The Site Planning Roundtable, consisting of a national cross-section of diverse planning, environmental, homebuilder, fire, safety, public works, and local government personnel, developed 22 "model development principles" in an effort to encourage environmentally sensitive, economically viable, and locally appropriate development. The resulting manual, Better Site Design: A Handbook for Changing Development Rules in Your Community (Brown et al., 1998), describes each principle, contrasts current and recommended practices for each, estimates economic benefits, and provides case studies where recommended practices were implemented. The Consensus Agreement on Model Development Principles to Protect our Streams, Lakes, and Wetlands (Site Planning Roundtable, 1998) provides a summary of the Roundtable's findings, including key points of consensus and a list of the 22 model development principles. Both documents can be ordered from the Center for Watershed Protection's web site at www.cwp.org.

C. Management Practices

The majority of management practices in this section are included in "better site design," which is a suite of site planning techniques that modify the layout of new developments to reduce the total paved area, conserve natural habitats, and better distribute and infiltrate runoff. All aspects of an individual site, including soil types, slopes, and the location of environmentally sensitive features such as wetlands, forests, and meadows, should be scrutinized to identify areas that should be preserved or restored. Better site design techniques are used to identify the most efficient building and infrastructure layouts and to develop a comprehensive strategy to reduce the quantity of runoff leaving the site and curb the amount of pollutants generated on-site.

There are many advantages to better site design. Environmentally friendly site designs are more likely to be accepted by local governments and the community, thereby speeding the plan approval process. Also, site designs that preserve community open space reduce the burden on the local government to provide recreational areas. Economically, better site design techniques reduce the amount and cost of infrastructure, which also reduces engineering and maintenance costs. From a marketing perspective, studies have shown that lots abutting forested or other open space are initially valued higher than lots with no adjacent open space, and over time their value appreciates more than lots in traditional subdivisions (Arendt, 1996). For example, lots in an open space subdivision in Amherst, Massachusetts, experienced a 13 percent greater appreciation in value over a comparable traditional development after 20 years, even though the lots in the traditional development were twice as large (Arendt, 1996).

From a quality of life standpoint, site designs that incorporate pedestrian paths and common open space foster a greater sense of community among residents. House lots are closer together, encouraging communication among neighbors. Additionally, common open space provides recreational opportunities that further encourage community interaction.

Finally, better site design offers environmental benefits, including protection of ecologically significant natural resources, reduction of runoff, and preservation of open space and wildlife habitat. Maintaining open space also increases the opportunity for alternative sewage and wastewater disposal and treatment practices such as land treatment, spray irrigation, and reclamation and reuse. In addition, the flexibility of better site design allows designers to site these wastewater treatment systems in the areas of the development best suited for them.

Overall, the practices presented in this management measure provide many advantages over traditional developments and can be implemented in most communities. In some cases, however, outdated development rules might discourage or prohibit some of these practices. Watershed managers should review the local building codes and regulations that govern new developments to determine whether better site design techniques are allowed or encouraged. The Center for

The second edition of the Bay Area Stormwater Management Agencies Association's *Start at the Source*, which was originally published in 1997, is an excellent resource on site design issues for watershed managers. This publication emphasizes the importance of considering runoff quality in the early stages of land planning and design. The new edition has been updated and expanded to include commercial, industrial, and institutional development, as well as a technical section that provides more detailed information on the characteristics, applications, design criteria, maintenance, and economics of the practices discussed in the document. More information about ordering this publication when it becomes available is provided on the Bay Area Stormwater Management Agencies Association's web site at *www.basmaa.org* (BASMAA, no date).

1. Site Planning Practices

a. Fit the site to the natural gradient

Retaining the existing topography of a development site assists in maintaining natural drainage features and depressional storage areas that help infiltrate and attenuate flows and filter pollutants. Depressional storage areas, commonly found as ponded areas after storms or during the wet season, aid in reducing runoff volumes and trapping pollutants. To help preserve natural drainage, a developer can (Goldman et al., 1986)

- Construct buildings and parking areas on existing flat terrain.
- Locate buildings and roads along existing contours.
- Orient long buildings with the major portion parallel to contours.
- Stagger floor levels to adjust to gradient changes.

b. Practice site fingerprinting

The total amount of disturbed area in a site can be reduced by fingerprinting development. Fingerprinting places development away from environmentally sensitive areas (wetlands, steep slopes, etc.), future open spaces, areas with trees to be saved, future restoration areas, and temporary and permanent vegetative forest buffer zones. At a subdivision or lot level, ground disturbance is confined to areas where structures, roads, and rights-of-way will exist after construction is complete. Other site-level fingerprinting practices include reducing paving and compaction of highly permeable soils, minimizing the size of construction easements and material storage areas, minimizing impervious areas in the site design, clearly demarcating the disturbance area, maintaining existing topography and drainage divides, and disconnecting impervious areas (Prince George's County, Maryland, Department of Environmental Resources, 2000a).

c. Use cluster development

Cluster development is used to concentrate development and construction activity on a limited portion of a site, leaving the remaining portion undisturbed. Figures 4.2 and 4.3 show schematics of a residential cluster development and a rural cluster development, respectively. This practice allows for the design of more effective erosion and sediment control and urban runoff management plans. It also provides a mechanism to preserve environmentally sensitive areas and reduce road lengths and impervious parking areas.

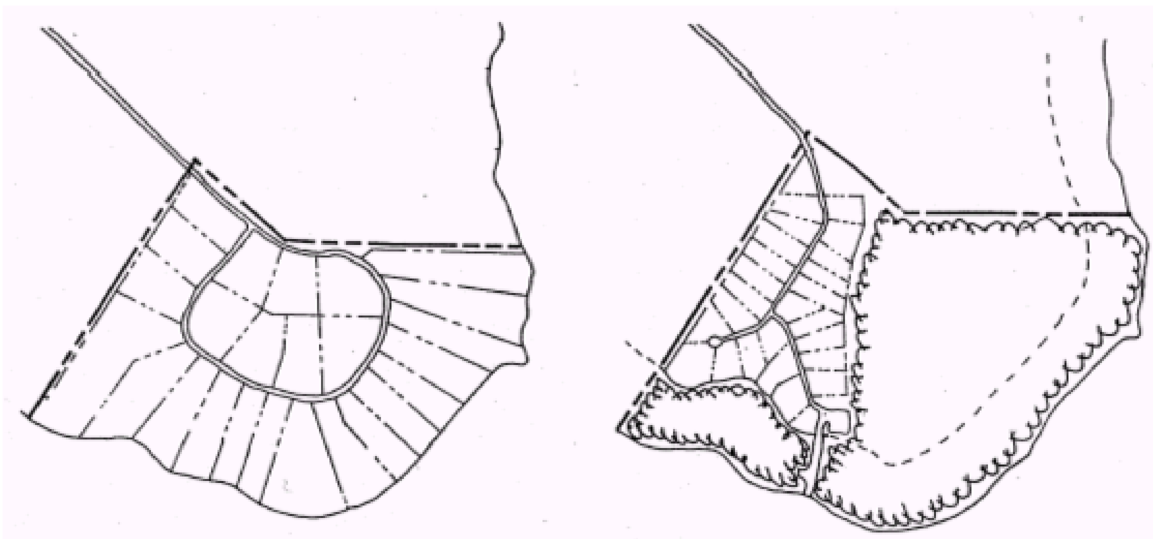

Figure 4.2: Schematic of a residential cluster development (Schueler, 1995).

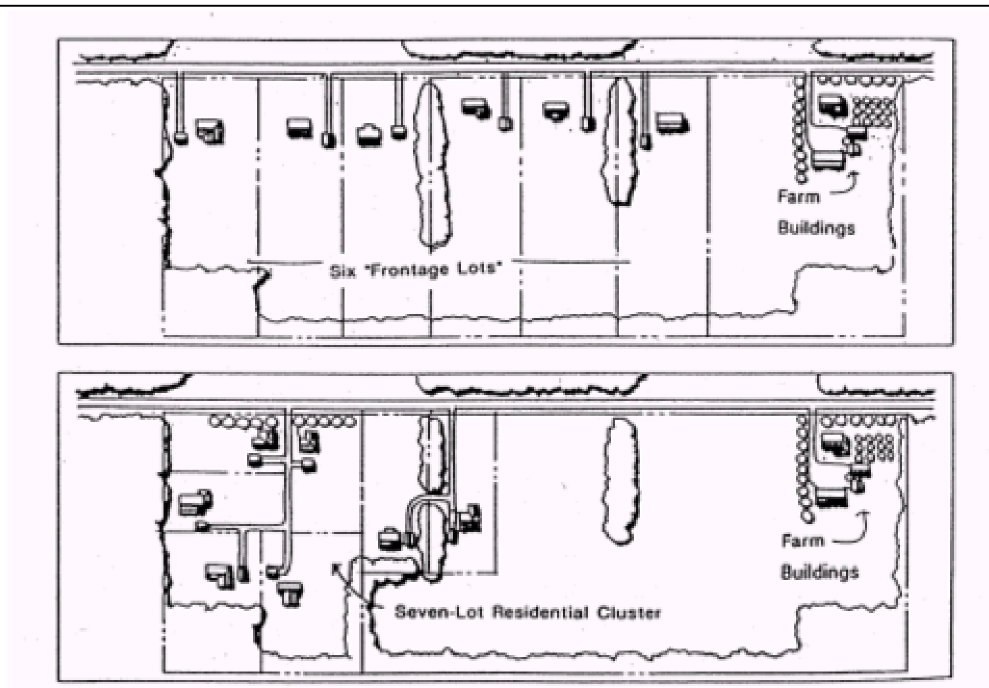

Figure 4.3: Schematic of a rural cluster development (Schueler, 1995).

Although a common belief is that low-density development is more environmentally sound because it results in increased open space, minimum lot size requirements can result in suburban sprawl. Many of these areas are heavily landscaped and therefore have the potential to contribute significant loadings of nutrients and pesticides to surface waters. Often, clustering and infill development are more environmentally sound and can result in a cost savings for municipalities because clustering and infill development typically require less new infrastructure, including urban runoff treatment systems. The imposition of density controls might preclude clustering. Although minimum lot size requirements are useful in some instances, such as farmland preservation (see Management Measure 3), zoning ordinances should not preclude the implementation of clustered development as an alternative to traditional suburban development.

d. Create open space

Open-space development is a technique that concentrates development on one area of a site in exchange for open space in another area. Benefits associated with open-space design include

- A 40 to 60 percent reduction in impervious cover compared to conventional development designs.
- Increased property values.
- Reduced construction and development costs.
- Common use recreational facilities, such as pedestrian paths, picnic areas, and athletic fields.

The following are some techniques for conserving open space:

- *By-right open-space development*. This technique allows for increased density on one portion of a site in exchange for open space on another portion. A large percentage of this open space can be dedicated as conservation land. To encourage open-space development, municipalities can draft ordinances so that this is a "by-right" option, as opposed to a special exception or variance.
- *Density compensation*. This technique allows developers to increase housing density to offset potential housing lots lost to on-site buffers or other conservation lands.
- *Storm water credits*. These credits take into account implementation of source controls that reduce runoff volumes and pollutant concentrations before the runoff reaches structural controls. Because performance is typically measured by comparing influent runoff to effluent runoff, storm water credits benefit operators of structural controls because they allow for the fact that removals already occurred through source controls.
- *Property tax credit*. The property tax credit is a technique for reducing, deferring, or exempting property taxes on conservation land. Typically, conservation easements are exchanged for the property tax credit.

– *Density bonus*. This bonus allows developers to increase density above base zoning density in exchange for conserving natural areas.

– *Off-site mitigation*. This term refers to the restoration or creation of wetlands in a designated off-site area if on-site wetlands are adversely affected and on-site mitigation is not feasible.

Case Study: Jordan Cove Urban Watershed National Monitoring Project

A study is being conducted by the Jordan Cove Urban Watershed National Monitoring Project in cooperation with EPA, Connecticut DEP, a University of Connecticut researcher, the town of Waterford, Connecticut, and a local landowner to compare the differences in runoff quantity and quality emanating from two sites, a traditional development and an environmentally sensitive development (Cote et al., 2000). Preconstruction monitoring revealed that the two sites could be used for a paired watershed monitoring design. This project has a treatment period that will occur in two phases—during construction and after construction when the runoff control practices are fully operational. Runoff quality and quantity are being measured at the outlets of each of the neighborhoods and in the control watershed. The runoff is analyzed weekly for suspended solids, phosphorus, and nitrogen. Grab samples are analyzed for fecal coliforms and 5-day biological oxygen demand (BOD_5), and monthly analyses are conducted for copper, lead, and zinc. Supplemental monitoring will be conducted on selected management practices to evaluate their effectiveness.

Preliminary findings include the following:

– An indication that construction of the traditional neighborhood is converting the watershed's topography from a "knoll" to a "bowl," which has caused a significant change in hydrologic response.

– Increased nitrate and lead concentrations in runoff.

– No increases in sediment and sediment-associated nutrients in runoff.

– A decline in total Kjeldahl nitrogen concentrations during construction.

Preliminary results suggest that increased runoff, rather than erosion, is the cause of increased pollutant export from the construction site.

Case Study: Nutrient Export from Conventional vs. Open-space Development in Maryland

Zielinski et al. (2000) undertook a study to compare nutrient export from several conventional development projects and the same projects designed using alternative open-space strategies. One site was a low-density residential subdivision in Maryland. In the conventional design, each lot had an on-site private septic system and the neighborhood had a septic reserve field of approximately 10,000 square feet. When the site was redesigned to preserve open space, the individual septic systems were replaced with shared septic systems that used more advanced recirculating sand filter technology with better nutrient removal capacity and lower construction and installation costs. When the two development scenarios were modeled to determine relative rates of nutrient export, the redesigned septic system showed a substantial decrease in nutrient output. However, despite the use of more advanced technology, septic systems were the predominant source of exported nutrients.

Comparison of Traditional and Low-Impact Development Scenarios in Delaware

The Brandywine Conservancy and the Delaware Department of Natural Resources and Environmental Control presented a case study in *Conservation Design for Stormwater Management* (Delaware DNREC and the Brandywine Conservancy, 1997). The case study compares conventional site development to several alternative, low-impact development scenarios at Chapel Run, a 96-acre site in Sussex County, Delaware. The Chapel Run site is located in a rural area and is categorized by Sussex County as a primarily agricultural area where low-density residential development is permitted. Conservation areas that were identified through a site investigation include a large area of woodland, much of which is on well-drained soils that generate little or no runoff, and a small area with steep slopes.

The proposed conventional design dictates dividing the site into 142 lots ½ acre in size. The conventional design does not take into consideration the sensitive areas identified in the site assessment and results in a site with 100 percent of the area disturbed after clearing and grading. Overall site imperviousness under conventional development would be 29 percent, assuming conventional road widths. On-site runoff management would be accomplished by a curb and gutter system that conveys runoff to two detention basins.

Two alternative designs were developed for the Chapel Run site: the parkway design and the village cluster design. Figure 4.4 shows lot layouts for the conventional and conservation designs. Table 4.3 shows a side-by-side comparison of the three types of developments with respect to lot size and layout, amount of disturbed and impervious area, hydrology, and costs.

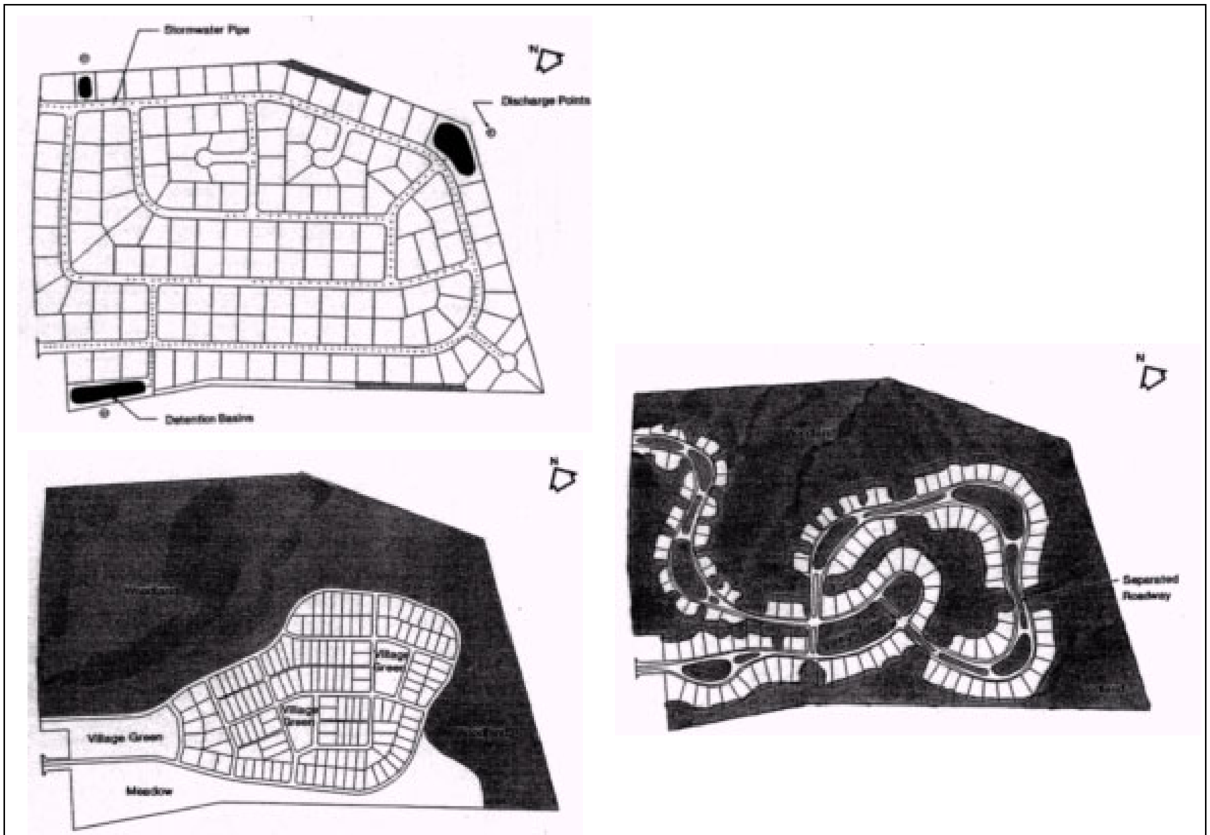

Figure 4.4: Schematic drawings of conventional (a), parkway (b), and clustered (c) development scenarios for the Chapel Run subdivision (Delaware DNREC and the Brandywine Conservancy, 1997).

Comparison of Traditional and Low-Impact Development Scenarios in Delaware (continued)

Table 4.3: Comparison of conventional and low-impact alternative designs for the Chapel Run site (DE DNREC and the Brandywine Conservancy, 1997). (Reductions are compared to the conventional design.)

Name	Conventional	Village	Parkway
Layout type	Conventional	Condensed cluster	Lots configured along curving road
Number of lots	142	142	142
Lot size	½-acre	⅛-acre	¼-acre
Areas conserved	None	Woodland and high recharge areas	Woodland and high recharge areas
Percent of site in open space	0%	72.7%	49.7%
Impervious cover	29%	17.7%	14.9%
Impervious cover reduction	—	38%	48%
Street width	28 feet	20 feet	Two one-way lanes 12 feet wide with a pervious median
Undisturbed areas	0%	67.5%	59.6%
Runoff management system	Curb and gutter system that conveys runoff underground to two detention basins.	Swale conveyance system along roads that directs runoff to retention/ infiltration areas with level-spreading devices and low berms. These retention/infiltration areas are located throughout the site. Several village greens established on well-drained soils function as both recreation and infiltration areas.	Infiltration of runoff into depressed median (swales) along streets. Wide oval parkway centers used for retention/infiltration. These areas are designed with overflow piping to prevent flooding.
Average curve number[a]	78	66	65
Peak runoff rate for a 10-yr storm[a]	—	53 cfs	51 cfs
Water budget (gal)			
Precipitation	114,082,682	114,082,682	114,082,682
Runoff	31,584,217	21,812,868	17,782,776
Recharge	31,280,103	34,001,079	35,502,938
Evapotranspiration	51,223,261	58,208,796	60,802,278
Costs			
Total	$2,460,200	$1,174,716	$888,735
Per lot	$27,325	$8,273	$6,259

[a] From USDA-NRCS's TR-55 model.

Randall Arendt (1996), in his book *Conservation Design for Subdivisions: A Practical Guide for Creating Open Space Networks*, presents a plain-language, illustrated guide for designing open-space subdivisions. This publication is available from Natural Lands Trust, Inc., 1031 Palmers Mill Road, Media, PA 19063; phone 610-353-5587. The following topics are covered:

- Open space vs. conventional developments.
- Economic, social, and environmental benefits of open-space designs.
- Roles and responsibilities of stakeholders in site development.
- A stepwise approach to designing an open-space subdivision (discussed below).
- Ideas for creating an interconnected open-space network.
- Seven case studies.
- Methods to modify existing regulations to encourage open-space design.
- Management techniques for conservation lands.
- Sample house plans for open-space subdivisions.
- Sample advertisements for developers to capitalize on open-space design benefits.
- Model ordinance provisions.

Arendt's multistep process for creating conservation subdivisions involves two stages. The first stage, called the background stage, involves identifying the characteristics of the surrounding landscape and existing development and analyzing and delineating significant features of the site. The second stage involves integrating the site feature information into a map and prioritizing conservation lands based on the features deemed most important while maintaining the quantity of land necessary to develop the site to the desired density.

The background stage involves examining the surrounding landscape and existing development to identify primary and secondary conservation areas. It includes the following practices:

(1) *Understanding the locational context*. The layout of new development should consider proximity to traditional small towns or villages; if existing development is nearby, the design of the new community should reflect and extend the historical streetscape and pattern. In rural areas located away from existing development, informal, irregular, "organic" layouts can be used successfully without detracting from the surrounding landscape.

(2) *Mapping natural, cultural, and historic features.* A thorough analysis of a site's special features that may enhance or constrain development is an important step in planning a new development. Special features might already have been identified in a natural resources inventory conducted by local government or land trust organizations. Primary conservation areas are legally or logistically unbuildable and therefore must be avoided. Secondary conservation areas are typically legally buildable but are historically or ecologically significant or desirable and therefore should be avoided when other land is available for development. The site analysis should include site visits and identify the following primary conservation areas:

  - *Wetlands*. Tidal and nontidal saltwater and freshwater wetlands and the dry upland buffers surrounding them should be identified as areas to be conserved because they function to filter runoff, provide critical habitat at the land-water interface, and offer opportunities for recreation and environmental education. Soil survey maps, National

Wetlands Inventory maps, state or environmental agency wetland maps, or on-site delineations can be used to determine the extent of wetland habitat on the site.

- *Floodplains*. The 100-year floodplain, which can be determined from floodplain maps published by the Federal Emergency Management Agency (see Management Measure 2), should not be developed to preserve a continuous riparian greenway and to prevent damage to property from flooding. To preserve views to the water on wooded sites, lower tree limbs can be removed. (This may be a reasonable alternative to developing closer to the water's edge.) Zoning requirements might dictate an additional 50- to 100-foot setback from the 100-year floodplain.

- *Slopes*. Slopes of more than 25 percent should not be developed because of their high potential for erosion. Slopes between 15 and 20 percent can be developed using special site planning but should be avoided when possible. Slope maps can be prepared from USGS topographic maps by an engineer, planner, or landscape architect, but site visits should confirm these conditions.

The following secondary conservation areas should also be identified.

- *Soils*. Soil surveys, whether they are based on existing maps produced by NRCS or data gleaned from on-site testing, identify well-drained soils suitable for treating wastewater, poorly drained soils that might result in leaky basements or wetland conditions, and steep or stony soils that would be difficult to build on. Existing soil survey data might not be detailed enough to characterize site conditions, depending on the spatial variability of soil types in the region. High-intensity soil surveys and site surveys that are accurate to 0.1 acre should be used in highly variable circumstances.

- *Significant wildlife habitats*. Habitat for threatened or endangered wildlife, including travel corridors to food sources, homes, and breeding grounds, should be conserved. An additional buffer of open space is recommended. These habitat locations might have been officially documented already by state or local agencies. Habitat for wildlife species that are not threatened or endangered should also be considered for conservation areas where possible. Continuity in habitat areas is important: land that connects two isolated habitat areas provides a valuable corridor that extends the usable habitat for the species of concern.

- *Woodlands*. Woodlands often provide valuable wildlife habitat and contribute to the aesthetic value of a property. Where areas are mostly forested and clearing is required for site development, however, areas of mature forest or areas with unique species composition should be of higher conservation priority. In areas where woodland is not the predominant land use, as much of the existing tree cover as possible should be conserved on the property. An effort should be made to maintain corridors that connect forested areas to provide as much continuous forested habitat as possible.

- *Farmland*. Agricultural lands can be conserved as open space if desired, although relatively small fields might not be lucrative and could pose a more significant water quality risk compared to residential development due to specific land management practices (tilling, fertilizer application) associated with agriculture. Another option for agricultural fields is to let them succeed to a more natural meadow state with grasses, wildflowers, and shrubs that could provide habitat for many birds and small mammals.

- *Historic, archaeological, and cultural features*. Areas with historic significance can be identified from official lists such as the National Register of Historic Places and state and local inventories of historic and cultural resources. Landowners and local historians should also be consulted for detailed information about a site's history. Although historic areas are not always protected from demolition, if other areas of the property are equally suitable for development, historic resources should be preserved.

- *Views into and out from the site*. Development should be designed to blend well with the surrounding landscape. Developers typically want to site buildings to take advantage of attractive views, siting buildings in areas where they are easily seen from the surrounding landscape. Siting buildings away from the pinnacles of ridges and hills, designing buildings with lower profiles, and preserving or planting trees to shield buildings from view are all techniques that can be used to reduce the visual impact of development on the landscape. Views can be created with limited cutting of trees to create "view tunnels" or trimming lower limbs to create "view holes" through the foliage.

- *Aquifers and their recharge areas.* Ground water aquifers are typically recharged at low points in the landscape or through sandy or gravelly soils. These areas, though generally buildable, should be conserved as open space to maintain ground water recharge. These areas should also be buffered with vegetation to filter solids and associated pollutants from runoff.

After background information has been obtained, the next step is to integrate the information and prioritize conservation areas. Typically all of the features mentioned above are drawn onto overlay sheets or entered into a geographic information system (GIS). Once the significant features are shown together, areas most suitable for development become obvious. Where some secondary conservation areas need to be sacrificed to achieve the development objectives, decisions will need to be made that rank the secondary conservation areas with respect to how special, unique, irreplaceable, environmentally valuable, historic, or scenic they are compared to similar features. Figure 4.5 shows an example site before development, developed with a conventional strategy, and developed with consideration of locational context and conservation areas (Arendt, 1996).

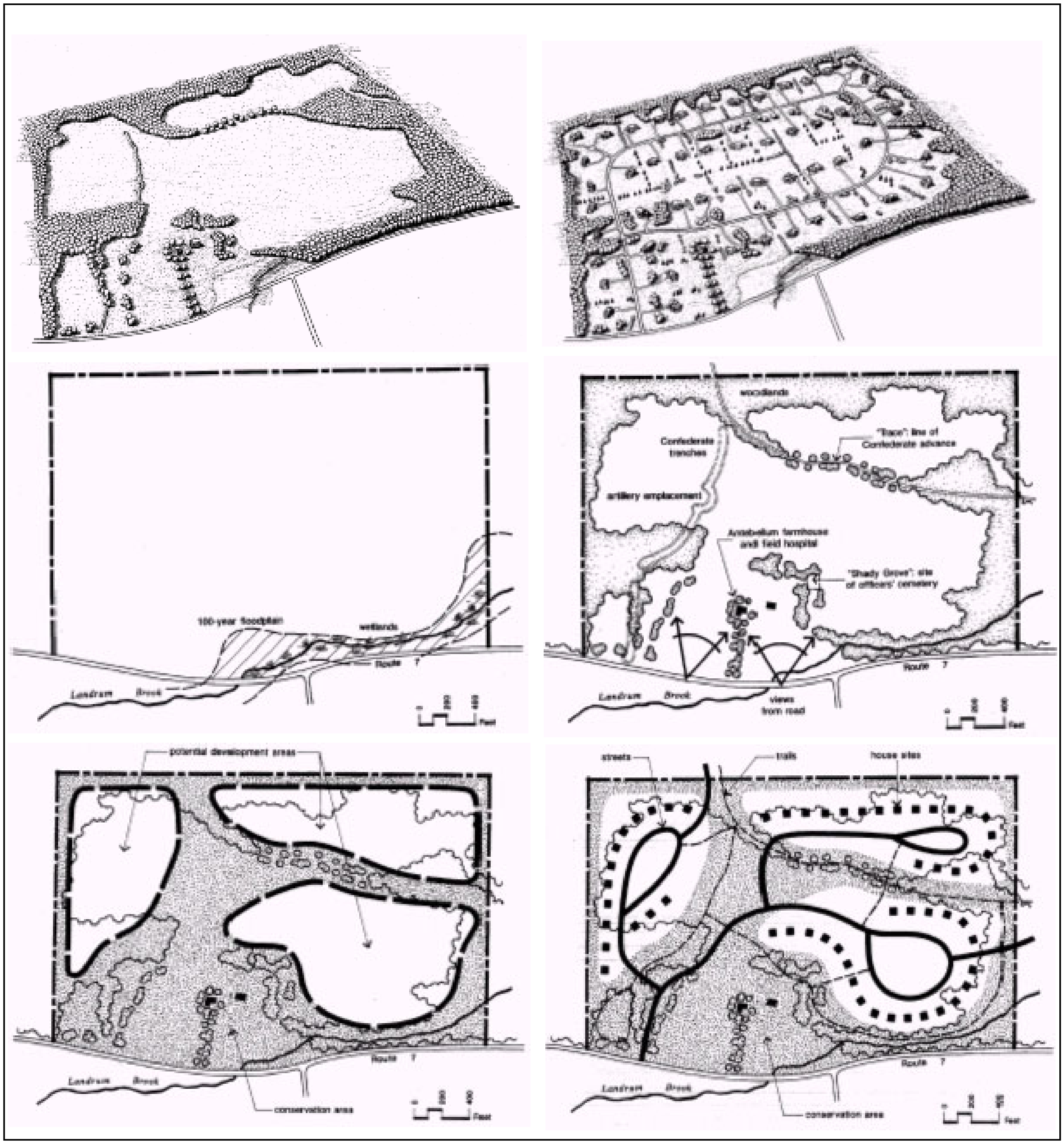

Figure 4.5: Development of a conservation subdivision. The site before development (a) and as designed with conventional development (b and c); identification of primary (d) and secondary (e) conservation areas; and delineation of potential development areas (f) (adapted from Arendt, 1996).

Pedestrian Paths Improve Neighborhood "Walkability"

Communities can improve the transportation infrastructure of neighborhoods by providing paths for pedestrians (Kiesling, 1999). This practice reduces automobile traffic, decreases the demand for parking, and promotes socializing among members of the community. Neighborhood paths reduce walking distances by offering quick "shortcuts" and improve safety by separating pedestrians from traffic.

There are several options for communities to incorporate pedestrian paths into neighborhood layouts, from making short connections between cul-de-sacs and major streets to creating extensive networks of pedestrian pathways. Pedestrian walkways also can be incorporated into the design of commercial parking areas, along riverfronts, in urban parks, and within plazas between buildings. Figure 4.6 shows how pedestrian paths can improve the "walkability" of a standard suburban neighborhood.

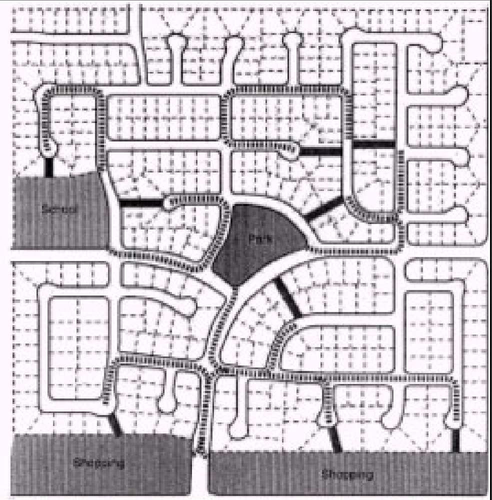

Figure 4.6: Pedestrian paths (bold lines) can add to the "walkability" of a neighborhood when compared to the sidewalk route (dotted lines).

2. On-Lot Impervious Surfaces

a. Reduce the hydraulic connectivity of impervious surfaces

Pollutant loading from impervious surfaces can be reduced if the impervious area does not connect directly to an impervious conveyance system. This can be done in at least four ways:

(1) Route runoff over lawn areas to increase infiltration.

(2) Discourage the direct connection of downspouts to storm sewers or the discharge of rooftop downspouts to driveways, parking lots, and gutters.

(3) Substitute swale and pond systems for curbs and gutters to increase infiltration.

(4) Reduce the use of storm sewers to drain streets, parking lots, and backyards.

Figure 4.7 shows schematic representations of impervious areas that are directly connected and not directly connected (BASMAA, 1997).

b. Practice rooftop greening

Rooftop greening has become an increasingly common practice in Europe and other parts of the world. This practice involves growing vegetation on the roofs of businesses and homes to intercept rainfall and promote evaporation rather than runoff (Natural Carpets, 1998). Rooftop mats are typically multilayered and include prevegetated coir fiber mats, a mineral-based substrate, and a synthetic matrix. The coir fiber mat absorbs rainfall, the mineral substrate provides the plants with nutrients, and the synthetic matrix promotes drainage. Mats can be used

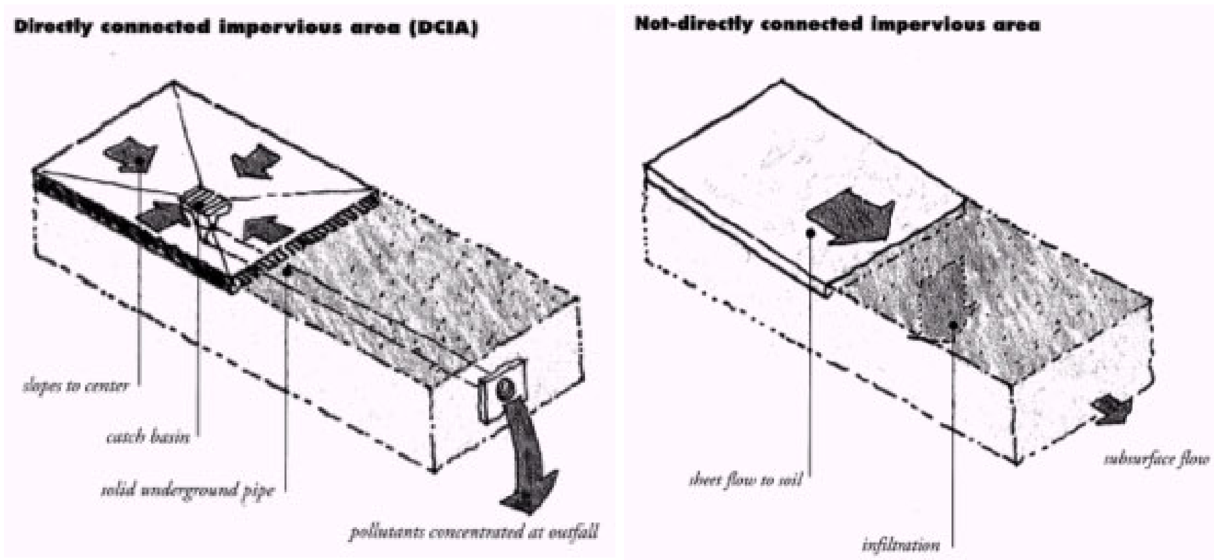

Figure 4.7: Schematic representation of directly connected and not-directly connected impervious areas (BASMAA, 1997).

on roofs with slopes of up to 30 degrees and are capable of reducing runoff by two-thirds. These mats provide benefits other than runoff reduction, including

- Visual aesthetics.
- Protection of roofs from damaging radiation, wind, and precipitation.
- Insulation.
- Noise reduction.
- Habitat for wildlife.
- Dust trapping.
- Evaporation and ambient cooling.

Vegetation should be well adapted to the growing conditions of the area where it is installed. Maintenance includes a limited amount of irrigation on steep slopes and periodic fertilization and weeding. Additional roof support might be necessary because the mats, when saturated with water, can add 5 to 17 pounds per square foot.

Building Green: A Guide to Using Plants on Roofs, Walls, and Pavements (Johnston and Newton, no date) is a reference for planting turf, gardens, and trees on roofs and walls. The book provides information on the effectiveness of ultra-urban greening at reducing runoff and energy consumption and on design techniques and plant suggestions, as well as European case studies where these practices have been successfully implemented. This publication is available from The London Ecology Unit, Bedford House, 125 Camden High Street, London, NWI 7JR; phone 071-267-7900.

Case Study: Rooftop Meadow Demonstration Project, Philadelphia, Pennsylvania

Rooftop meadows typically use foliage and a lightweight soil mixture to either absorb or filter and detain rainfall (Miller, 1998). Roof meadows are designed to control low-intensity storms by intercepting and retaining or storing water until the peak storm event has passed, while allowing the runoff from higher-intensity storm events to be safely conveyed away from the building. The plants help retain the hydrologic function of intercepting and delaying rainfall runoff by capturing and holding precipitation in the foliage, absorbing water in the root zone, and slowing the velocity of direct runoff by extending the flowpath through the vegetation.

A rooftop meadow demonstration project in Philadelphia, Pennsylvania, consists of a 3,000-ft^2 roof installed and monitored on top of an existing structure. The roof system was intended to mimic natural hydrologic processes of interception, storage, and detention to control the 2-year, 24-hour storm event. The distinguishing features of this rooftop meadow are

- A synthetic underdrain layer that promotes rapid drainage of water from the surface of the roof deck.

- A thin, lightweight growth medium that permits installation on existing conventional roofs without the need for structural reinforcement.

- A meadow-like setting of perennial *Sedum* varieties that have been selected to withstand the range of seasonal conditions typical of the Mid-Atlantic region without the need for regular maintenance.

The installed roof meadow is 3.4 inches thick, including the drainage layer, and weighs less than 5 lb/ft^2 when dry and less than 17 lb/ft^2 when saturated. The moisture content of the medium at field capacity is 45 percent of the volume. The saturated infiltration capacity is 3.5 inches per hour.

The runoff characteristics of the roof were simulated using rainfall records for 1994 from eastern Pennsylvania. The model predicted a 54 percent reduction in annual runoff volume and attenuation of 54 percent and 38 percent, respectively, for the 2- and 10-year, 24-hour Type II storm events. Monitoring of the pilot project for real and synthetic storm events was also conducted for a period of 9 months at 28- and 14-ft^2 trays. The most intense storm monitored was a 0.4-inch, 20-minute thunderstorm. The storm event occurred after an extended period of rainfall had fully saturated the medium. Although 44 inches of rainfall were recorded during this period, only 15.5 inches of runoff were generated from the trays. Runoff was negligible for storm events with less than 0.6 inch of rainfall. This demonstration project shows the advantages of reducing peak runoff rates on overloaded systems for a majority of the storm events and shows that existing structures can be retrofitted to reduce runoff.

c. Relax frontage and setback requirements

Open-space developers typically increase housing density by creating smaller lots or clustered developments and pool the space “savings” in a large open area accessible to all. This can be accomplished by reducing front, side, and rear yard setbacks and decreasing frontage distances. In addition to increasing housing density for open-space development designs, relaxing frontage and setback requirements also decreases impervious cover. This occurs because narrower side yards mean narrower lots, which can in turn lead to shorter subdivision streets, and shorter front yard setbacks lead to shorter driveways and sidewalks.

d. Modify sidewalk standards

Many traditional subdivision codes require paved sidewalks on both sides of the street in widths that range from 4 to 6 feet. Communities that want to reduce impervious cover and increase the use of pervious areas for runoff treatment should consider the following:

- Reducing sidewalk width to 3 feet.
- Allowing sidewalks on only one side of the street, eliminating them altogether, or building them only where there is pedestrian demand.
- Increasing the distance between sidewalks and the street so sidewalk runoff has a better chance of infiltrating into the grass border area and not becoming street runoff.
- Grading sidewalks so that runoff drains to the front yard rather than toward the street.

Case Study: Greenways

A survey was conducted in the Chicago area to determine people's use and perception of greenway trails, which are natural or landscaped paths designed for recreational uses such as walking, jogging, and biking (Adams, 1999). Paul Gobster of the USDA Forest Service identified several factors that influence people's opinion of trails, including location, design, and management. He found that small, local trails were used repeatedly by local residents and that trails located close to home (within 8 km) were used most frequently. Most metropolitan area users preferred paved, landscaped trails with drinking water and clean restrooms located at reasonable intervals along the trail. Maintenance of the trail surface, crowding, use conflicts, and personal safety were other factors affecting people's use and perception of trails.

Based on the survey responses, siting trails close to residential areas, diligent maintenance of trail surfaces and facilities, planting and management of vegetation, and regular safety patrols would improve the perception and use of greenways by metropolitan area residents. In addition to recreational benefits, communities also provide habitat protection and preservation of biodiversity by establishing and maintaining greenways.

e. Modify driveway standards

In a sense, driveways are small-scale parking lots that are designed to accommodate two to four cars. When combined with areas needed to drive in and park, driveways can easily total 400 to 800 square feet. Communities that want to reduce driveway impervious cover should consider

- Shortening driveway length by shortening front yard setback requirements.
- Narrowing driveway widths.
- Encouraging the use of driveways that are shared by two or more homes.
- Providing incentives for use of alternative driveway surfaces that allow for infiltration, such as porous pavers, gravel, or a two-track surface with grass in between.

3. Residential Street and Right-of-Way Impervious Surfaces

The largest percentage of impervious cover in residential neighborhoods is typically associated with the streets, driveways, and sidewalks that together aid in the transport of people to and from their various destinations. Management practices associated with residential streets and their rights-of-way typically focus on minimizing impervious cover or treating runoff. In general, these objectives can be achieved by developing, updating, or revising codes, ordinances, and standards that determine the size, shape, and construction of residential streets and their rights-of-way.

a. Decrease street pavement width and length

Streets typically make up the largest percentage of transport system impervious cover in residential neighborhoods. Communities can significantly reduce this type of cover in new developments by revising street standards so that street pavement widths are based on traffic volume, on-street parking needs, and other variables rather than forcing all streets to have one universal width. Additionally, communities can encourage developers to design street networks that minimize the total length of pavement. The length of residential streets can be reduced by altering the design and placement of new development. Techniques include

- Reducing frontage distances and side yard setbacks.
- Allowing narrower lots.
- Clustering smaller lots.
- Reducing the number of non-frontage roads.
- Eliminating long streets that serve only a small number of homes.

b. Decrease street right-of-way width

A street right-of-way is a public easement corridor through which people, vehicles, runoff, utility services, and other items and materials move in, out, and around the development. A right-of-way usually includes the street itself, its gutters and curbs, and some amount of land on either side of the street, which might contain sidewalks, utility easements, or other components. Options for minimizing right-of-way widths include

- Eliminating some right-of-way components.

- Placing sidewalks on only one side of the street.

- Running utility pipes, cables, and other infrastructure underneath street pavement. (This can result in traffic congestion from road construction if the infrastructure needs to be repaired or replaced.)

- Reducing street and sidewalk widths.

On-street parking is a variable that should be closely examined in communities where reducing impervious cover is a goal. Some communities have implemented a concept known as "queuing streets." Queuing streets generally have one travel lane and one or two queuing lanes. Cars wait between parked cars in the queuing lanes until approaching traffic passes before proceeding to the travel lane. This approach also helps slow traffic, which can improve safety.

Case Study: The Headwaters Project: A Sustainable Community

In 1998 the Department of Planning and Development in Surrey, British Columbia, initiated the Headwaters Project to develop a real example of a sustainable community. Part of this project is the *East Clayton Neighbourhood Concept Plan* (The Headwaters Project, 2000), a green infrastructure plan that is an integrated system of "green" streets and affordable housing sites. It has narrow streets that use one-third less blacktop than typical roadways. Storm water management is achieved through natural infiltration, which minimizes runoff and avoids downstream flooding events. Information about East Clayton and a copy of the concept plan are available at *www.sustainable-communities.agsci.ubc.ca/projects/Headwaters.html*.

c. Use alternative cul-de-sac designs

Cul-de-sacs (roads with one open and one closed end) are a popular design element in community road networks. The intent of cul-de-sacs is to provide more homebuyers with premium, "end-of-the-road" lots. The typical "bulb" found at the closed end of a cul-de-sac, however, represents a particularly large concentration of impervious cover. Communities can reduce the amount of impervious cover created by bulb-ending cul-de-sacs by

- Eliminating cul-de-sac streets altogether.
- Using alternative designs for turnarounds, such as a T-shaped turnaround or a looped road.
- Reducing the radius of the turnaround bulb.
- Incorporating a pervious cover island in the center of the turnaround bulb that accepts runoff.

Figures 4.8 and 4.9 show five turnaround options at the end of a residential street and the amount of impervious cover created by each option (Schueler, 1995).

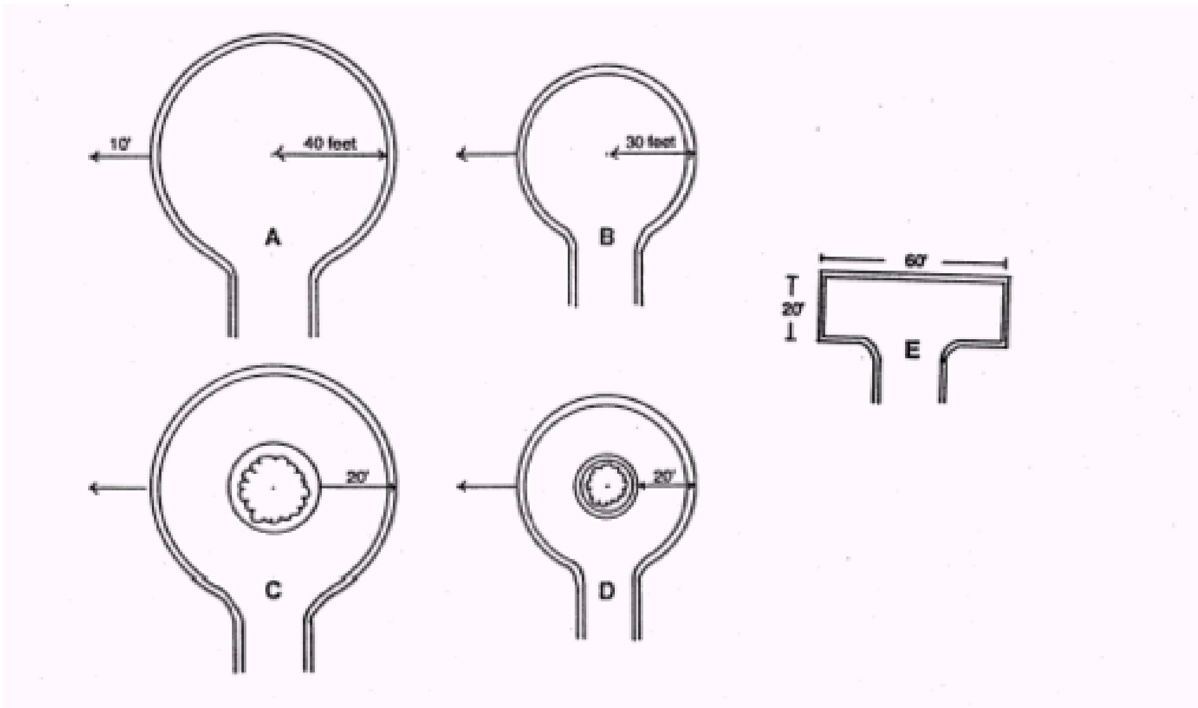

Figure 4.8: Five turnaround options at the end of a residential street (Schueler, 1995).

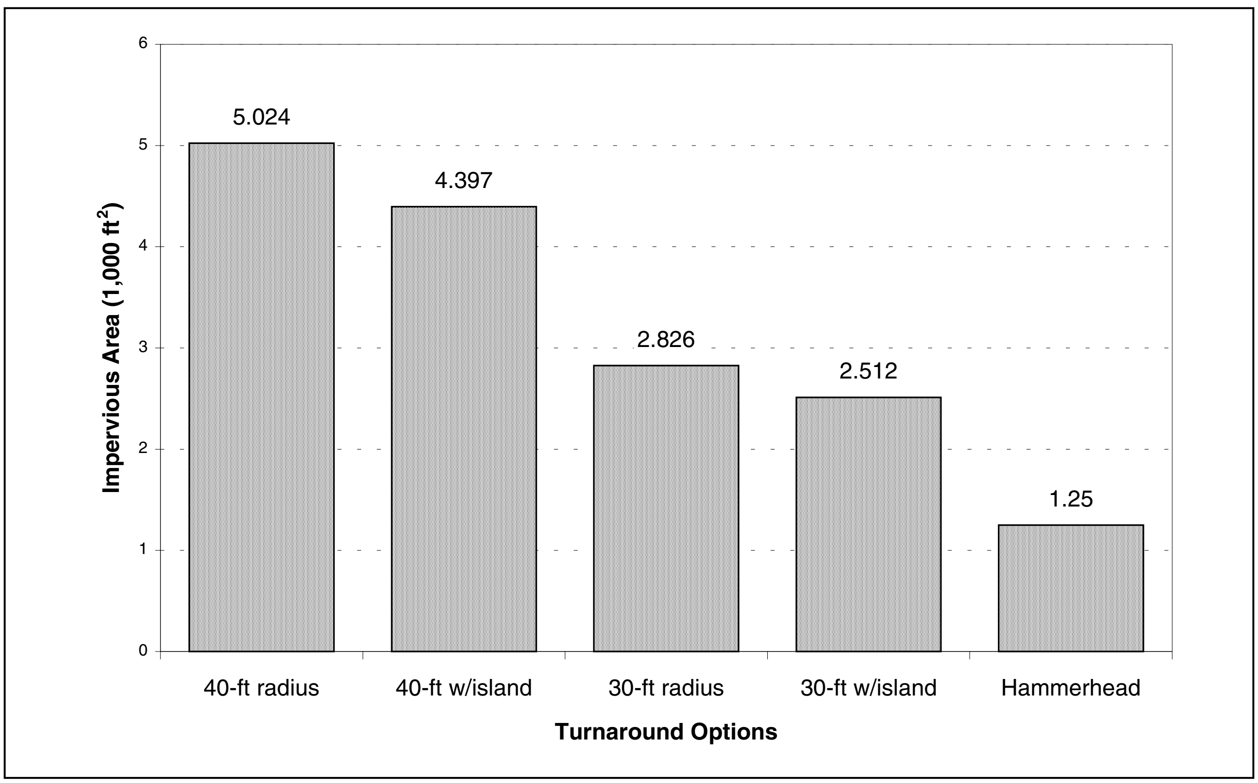

Figure 4.9: Impervious cover created by each turnaround option shown in Figure 4.8 (Schueler, 1995).

4. Parking Lot Impervious Surfaces

Parking lots are considered by some to be one of the most damaging land uses in the urban landscape (CWP, 2000). Not only are parking lots very efficient at concentrating and delivering a large amount of runoff to receiving waters, exacerbating erosion problems, but they also act as a repository for pollutants associated with automobiles, which include nutrients, trace metals, and hydrocarbons.

Traditionally, developers have provided an overabundance of parking as a convenience for shoppers, workers, and landowners. A goal of watershed managers should be to reduce the surface area of parking lots and integrate runoff treatment practices to reduce adverse impacts, while still providing enough spaces to meet the expected parking demand. This reduction can be accomplished by implementing several better site design practices, including

- Redesigning building and parking area layouts to reduce walking distances and provide more efficient layouts.

- Ensuring that the number of spaces built reflects actual demand. Site planners should design the lot size to correspond to minimum local parking requirements and consider ways in which this requirement can be reduced. For example, less parking is needed if access to public transportation is provided. Also, a parking area can be shared if adjacent localities have different peak parking times. For instance, a retail establishment with peak demand during weekdays can share parking with a church whose peak demand is on the weekend.

- Sizing parking lot dimensions to meet everyday demand and designating additional "spillover" parking areas to handle peak demand. Because these spillover areas will receive less traffic, alternative paving techniques (see Management Measure 5) can be used to increase infiltration.

- Reducing the dimensions of the normal parking spaces if allowable. Also, developers can designate a percentage of the available parking spaces for use by compact cars and reduce their dimensions correspondingly.

- Building multilevel parking structures when feasible. (Parking structures can sometimes be impractical from a cost standpoint.)

- Converting parking lot islands to bioretention areas (see Management Measure 5).

When parking area is reduced, functional landscaping can be used to improve the aesthetics of the site and to allow room for the installation of runoff treatment practices such as infiltration basins, filter strips, and dry swales or detention practices like those described in Management Measure 5.

Case Study: Innovative Turf Parking Lot Installation at a Connecticut Shopping Mall

The owners of Westfarms Mall, in the suburbs of Hartford, Connecticut, planned a 310,000-ft^2 expansion that required an additional 4 acres of overflow parking (Wilson et al., 1998). Local zoning boards and members of the community balked at this proposal because of the high ratio of impervious-to-pervious surfaces and concern for the quality and quantity of runoff generated by the new additions.

The traditional solution for handling the increased runoff was to install a large runoff detention pond, which would have cost $1million and was looked upon unfavorably by both the community and the mall owner. A 4-acre turf parking lot was implemented as an alternative and allows rainfall to infiltrate and recharge the ground water supply. To better support automobile traffic, the lot consists of a plastic honeycomb grid filled with sand and soil and laid atop a bed of crushed stone. Additionally, rooftop runoff is diverted to a tank located under the lot and the collected runoff is used to irrigate the turf. The turf would not hold up to everyday traffic, but overflow parking is needed only during the Christmas shopping season when the grass is dormant.

The cost of installing the turf lot was $500,000, which is half the cost of installing a pond. Even though the turf installation was more expensive than traditional pavement installation, the mall owner estimated that the installation would break even within 5 years because of lower maintenance requirements. An additional benefit of this innovative design was for the mall owner to gain the support of community members and local planning commissions.

5. Xeriscaping Techniques

Xeriscaping is a landscaping concept that maximizes water conservation by using site-appropriate plants and an efficient watering system. It also involves the use of landscaping plants that need minimal watering, fertilization, and pesticide application. Xeriscaping can reduce the contribution of landscaped areas to nonpoint source pollution and can reduce landscape maintenance by as much as 50 percent, primarily as a result of the following (Clemson University Cooperative Extension Service, 1991):

- Reduction of water loss and soil erosion through careful planning, design, and implementation.
- Reduction of mowing by limiting lawn areas and using proper fertilization techniques.
- Reduction of fertilization through soil preparation.

In 1991 the Florida Legislature adopted a xeriscape law that requires state agencies to adopt and implement xeriscaping programs. The law requires that rules and guidelines be adopted for the implementation of xeriscaping along highway rights-of-way and on public property associated with publicly owned buildings constructed after July 1, 1992. Local governments are tasked with determining whether xeriscaping is a cost-effective measure for conserving water. If so, local governments are to work with the state water management districts in developing their xeriscape guidelines. Water management districts will provide financial incentives to local governments for developing xeriscape plans and ordinances. These plans must include

- Landscape design, installation, and maintenance standards.
- Identification of prohibited plant species (invasive exotic plants).
- Identification of controlled plant species and conditions for their use.
- Specifications for maximum percentage of turf and impervious surfaces allowed in a xeriscaped area.
- Specifications for land clearing and requirements for the conservation of existing native vegetation.
- Monitoring programs for ordinance implementation and compliance.

Case Study: Water Conservation and Xeriscaping in Albuquerque, New Mexico

The City of Albuquerque, New Mexico, recently adopted a new strategy to encourage water conservation and to ensure a lasting water supply for years to come (Bennett, 1999). The strategy includes

- Reducing per capita water consumption by 30 percent.
- Developing facilities to treat and distribute city-owned surface water in combination with more limited use of the aquifer.
- Developing systems to use reclaimed wastewater and low-quality shallow ground water to irrigate landscaped areas in specific corridors of the community.
- Aggressive preservation of ground water quality.

The city also developed a new ordinance, the Water Conservation Landscaping and Water Waste Ordinance, that includes the following provisions:

- Prohibits irrigation water from flowing or spraying into streets, storm drains, or adjoining property.
- Limits high-water-use turf to 20 percent of the total landscape for all new developments.
- Establishes design requirements to discourage turf on steep slopes or adjacent to streets.
- Establishes water budget goals for parks and golf courses.
- Requires that new sprinkler systems on large turf areas meet minimum uniformity standards.
- Requires spray irrigation to occur between 6:00 p.m. and 10:00 a.m. from April to September.

The full text of the ordinance can be found at www.cabq.gov/resources.

As a result of these changes in Albuquerque's water conservation policy, the city's water consumption has decreased by 24 percent and its irrigation professionals have experienced a substantial increase in business as landowners seek smarter solutions to irrigation problems. Improvements in irrigation technology and increased public awareness are likely to further decrease water consumption.

The law also includes a provision requiring local governments and water management districts to promote the use of xeriscape practices in already developed areas through public education programs. California has passed a law requiring all municipalities to consider enacting water-efficient landscape requirements.

Information Resources

In 1991 the Center for Watershed Protection published the *Consensus Agreement on Model Development Principles to Protect Our Streams, Lakes, and Wetlands*, which outlines the series of 22 nationally endorsed principles developed by the Site Planning Roundtable, a national cross section of diverse planning, environmental, home builder, fire, safety, public works, and local government personnel, and details basic rationale for their implementation. The *Consensus Agreement* can be purchased at *www.cwp.org*.

The Center for Watershed Protection also published *Better Site Design: A Handbook for Changing Development Rules in Your Community* in 1998. This document outlines 22 guidelines for better developments and provides detailed rationale for each principle. Better Site Design also examines current practices in local communities, details the economic and environmental benefits of better site designs, and presents case studies from across the country. It can be purchased at *www.cwp.org*.

The Metropolitan Washington Council of Governments published *Clearing and Grading Strategies for Urban Watersheds* in 1995 to assist land planners and developers in preventing the adverse effects that result from clearing and grading of construction sites, especially those related to excessive erosion and high sediment loads in runoff. This document can be purchased from the Metropolitan Washington Council of Governments web site at *www.mwcog.org/ic/publist.html*.

Wildlife Reserves and Corridors in the Urban Environment: A Guide to Ecological Landscape Planning and Resource Conservation, by Lowell Adams and Louise Dove (1989), reviews the knowledge base regarding wildlife habitat reserves and corridors in urban and urbanizing areas and provides guidelines and approaches to ecological landscape planning and wildlife conservation in such areas. It can be purchased from the Urban Wildlife Resources Bookstore at *users.erols.com/urbanwildlife/bookstor.htm*.

In 1997 Randall Arendt of the Natural Lands Trust, Inc., published *Growing Greener: Putting Conservation into Local Codes*. *Growing Greener* is a statewide community planning initiative designed to help communities use the development regulation process to their advantage to protect interconnected networks of greenways and permanent open space. The booklet can be downloaded in PDF format at *www.natlands.org/pdffiles/growinggreener.pdf*.

The Watershed Management Institute published *Institutional Aspects of Urban Runoff Management: A Guide for Program Development and Implementation,* which presents a comprehensive review of the institutional frameworks of successful urban runoff management programs. It was developed to assist individuals responsible for developing and implementing urban erosion, sediment control, and storm water management programs. To order, send a check, money order, or purchase order to Watershed Management Institute, Inc., 410 White Oak Drive, Crawfordville, Florida, 32327. For more information, please contact Eric Livingston at 850-926-5310 or Earl Shaver at 410-758-2731.

The Low Impact Development Center was established to develop and provide information to individuals and organizations dedicated to protecting the environment and our water resources through proper site design techniques that replicate preexisting hydrologic site conditions. More information about this organization can be found on the Low Impact Development Center web site at www.lowimpactdevelopment.org or by contacting the Center at 301-345-0440.

The Prince George's County, Maryland, Department of Environmental Resources produced two documents, *Low-Impact Development Design Strategies: An Integrated Design Approach* (EPA-841-B-00-003) and *Low-Impact Development Hydrologic Analysis* (EPA-841-B-00-002), that discuss site planning, hydrology, distributed integrated management practice technologies, erosion and sediment control, and public outreach techniques that can reduce storm water runoff from new and existing developments. Both publications can be ordered free of charge through EPA's National Service Center for Environmental Publications at www.epa.gov/ncepihom/index.htm.

Residential Streets, prepared by the American Society of Civil Engineers, the National Association of Home Builders, and the Urban Land Institute (1990), discusses design considerations for residential streets based on their function and their place in the neighborhood. The publication presents guidance on street widths, speeds, pavement types, streetscapes, rights-of-way, intersections, and drainage systems.

The Institute of Transportation Engineers (ITE) published *Traditional Neighborhood Development—Street Design Guidelines* (1997), in which traditional neighborhood designs that support pedestrian movement over automobile traffic are discussed and design concepts such as on-street parking, street width, and sight distances are presented. The publication also includes a practical discussion of the time needed for community acceptance and travel behavior changes. ITE also published *Guidelines for Residential Subdivision Street Design* (1993), which presents a discussion of the overall design of a residential subdivision with respect to the adequacy of vehicular and pedestrian access, minimizing excessive vehicular travel, and reducing reliance on extensive traffic regulations. It also includes design considerations for local and collector streets and intersections, including such topics as terrain classifications, rights-of-way, pavements, curb types, and cul-de-sacs. These publications are available through the Institute of Transportation Engineers, 525 School Street, SW, Suite 410, Washington, DC 20024-2797, phone (202) 863-5486.

Street Design Guidelines for Healthy Neighborhoods is a guidebook intended to help communities implement designs for streets that are safe, efficient, and aesthetically pleasing for both people and cars. This publication can be purchased from the Local Government Commission's Center for Liveable Communities web site at www.lgc.org/bookstore/land_use/publications/healthystreets.html.

The Congress for the New Urbanism has compiled a database of jurisdictions across the country that have adopted reduced width street standards (Cohen, 2000). The database also includes resources related to neighborhood design and transportation. The database can be viewed at www.sonic.net/abcaia/narrow.htm.

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